Automated Arrival Traffic Flow Management Using 4D Trajectories

Dave Schleicher

Sensis Corporation
85 Collamer Crossings
East Syracuse, New York 13057

Tel: +1 315-445-0550   Fax: +1 315-445-9401
www.sensis.com   info@sensis.com

Detect the Difference

Outline

- **Why 4D Trajectories?**

- **Mature State 4DT System**
  - **Components**
  - **Roles & Responsibilities**
  - **Benefits**
  - **Roadmap**

- **Potential 2007 4DT Experiment**
  - **Goals & Method**
  - **System Architecture**
  - **Roles & Procedures**
  - **Future Evolution**

- **Next Steps**

Detect the Difference

4D Trajectories: A *Revolution* in ATM

Non-Radar Procedures

- Estimate Current Position
- Estimate Future Position

Radar Procedures

- Know Current Position
- Estimate Future Position

4D Trajectory Procedures

- Know Current Position
- Know Future Position

Sensis CORPORATION

Detect the Difference

Why 4D Trajectories?

- **A Future ATM System with**
  - 4D Trajectory (4DT)-based FMS-equipped Aircraft, and
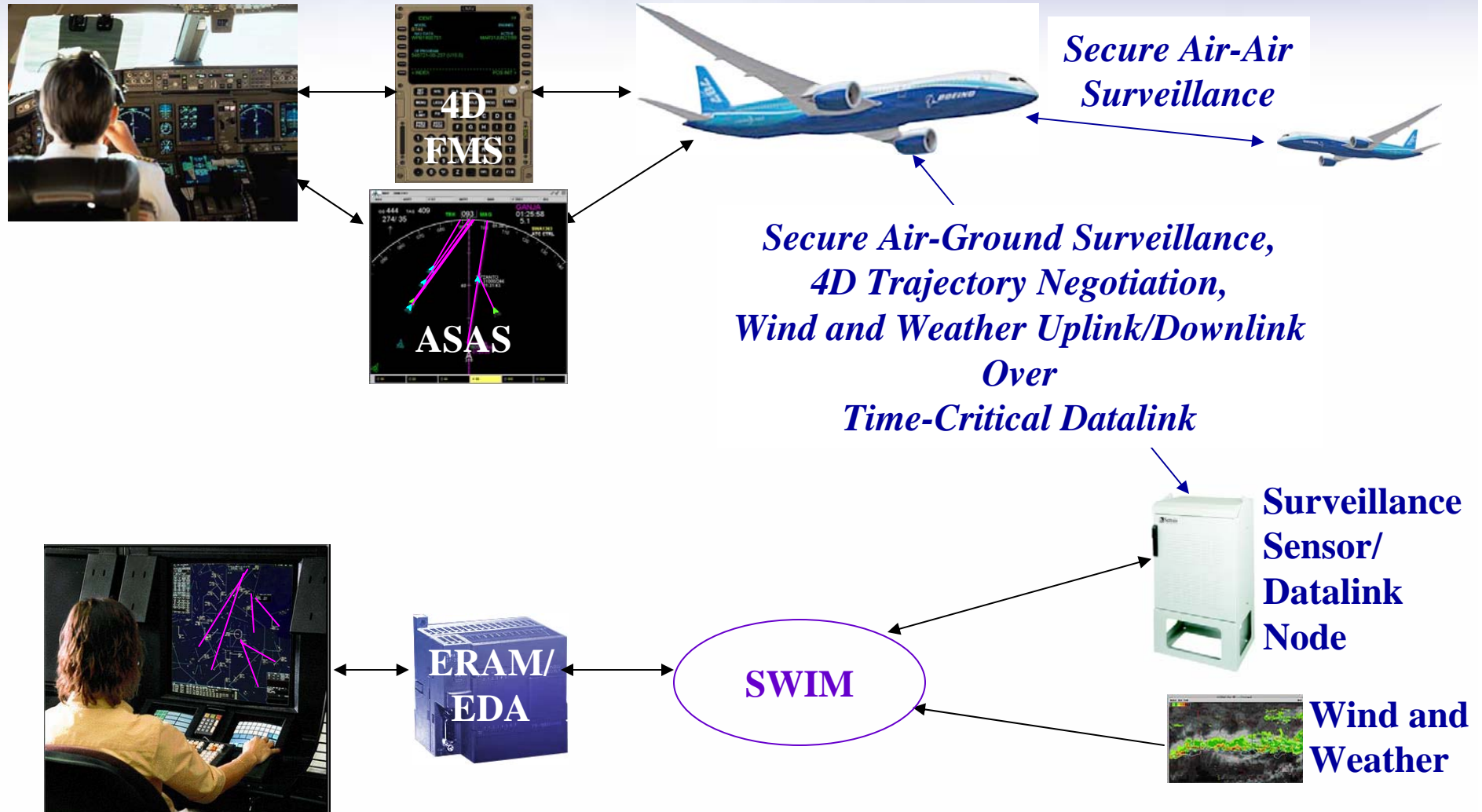 - 4DT-based ATM Ground Automation

  Means:
  - Improved Air-Ground Coordination of Intent,
  - Improved System Predictability,
  - Improved Air Traffic Planning, and
  - Reduced Flight Technical Error

  Which Should Result in:
  - Increased Situational Awareness
  - Increased Safety
  - Increased Capacity
  - Improved ANSP Productivity
  - Reduced Operating Costs, Fuel Burn, and Emissions

- **Significant JPDO, Eurocontrol and Industry Interest in 4D Trajectory Research and Implementation**
  - JPDO NGATS vision features 4DT-based operations

- *Need to show technical feasibility and operational viability*

Sensis CORPORATION

Detect the Difference

Mature State 4D System

4D FMS

ASAS

Secure Air-Air Surveillance

Secure Air-Ground Surveillance,
4D Trajectory Negotiation,
Wind and Weather Uplink/Downlink
Over
Time-Critical Datalink

Surveillance Sensor/ Datalink Node

ERAM/ EDA

SWIM

Wind and Weather

sensis CORPORATION

Detect the Difference

# Logical Airborne vs. Ground Automation Roles and Responsibilities

- *Generates and Downlinks User-Preferred Trajectory*
- *Generates and Downlinks Planned Trajectory*
- *Downlinks In-Situ Local Wind and Weather Information*

- *Determines Potential Conflicts*
- *Generates Conflict Resolutions*
- *Determines Time-Based Metering, when appropriate*
- *Determines and Uplinks Constraints to User-Preferred Trajectory*
- *Uplinks Wide-Area Wind and Weather Forecast Information*

Traffic Scenario

Low Density   **High Density**
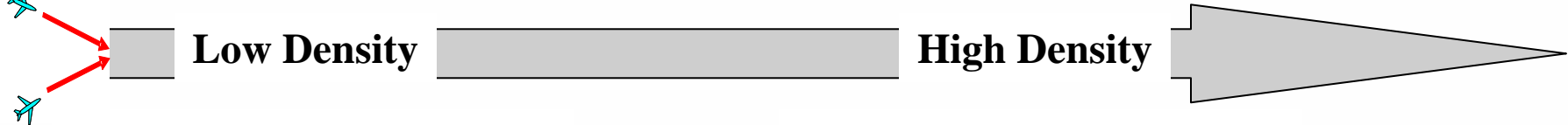
**Airborne Automation is
main driver of trajectory**

**Ground Automation is
main driver of trajectory**

sensis CORPORATION

Detect the Difference

4D Trajectory Negotiation: Benefits

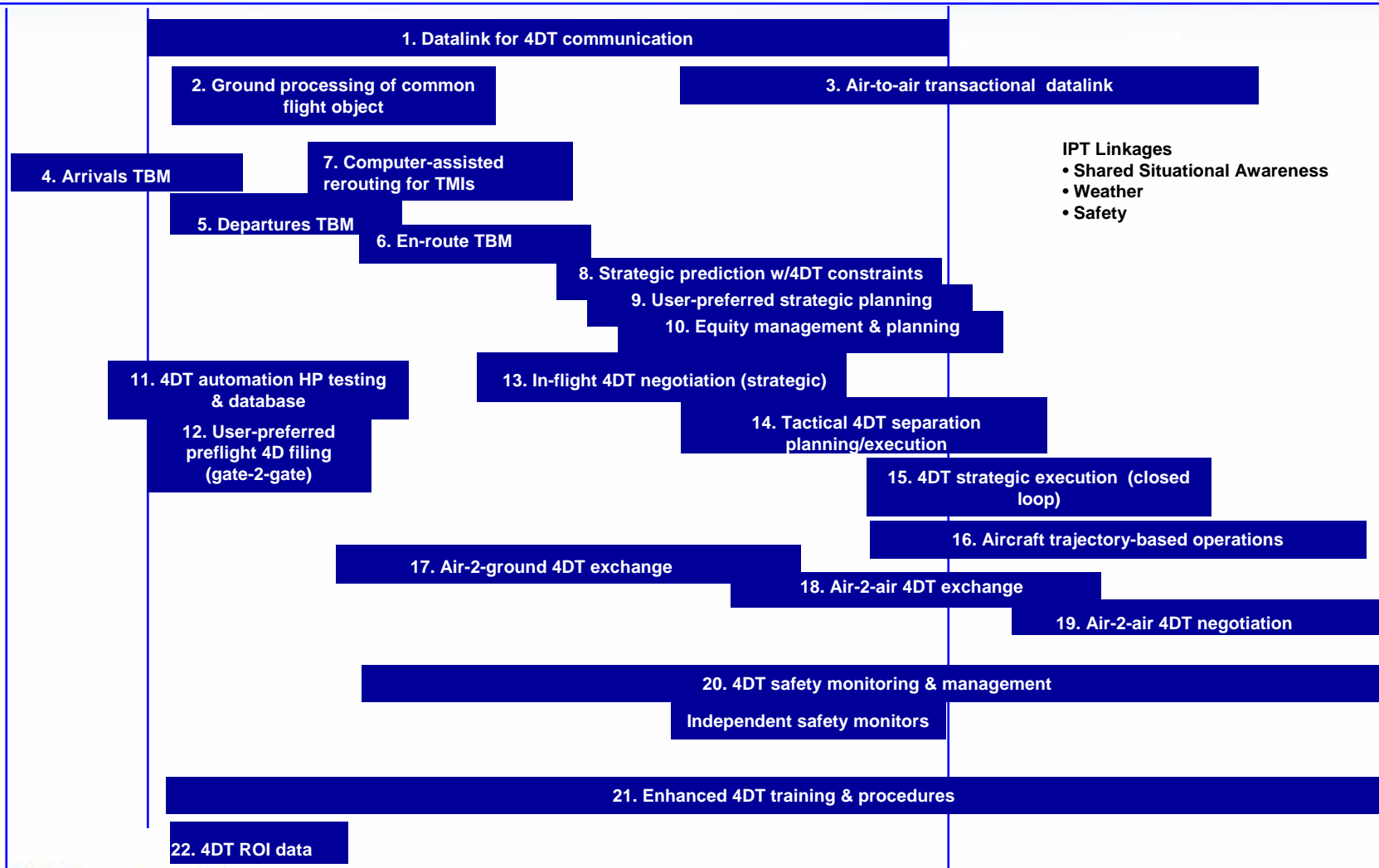| Stakeholder	Benefits
Flight Crews (NAS Users) **Air Transportation Providers: (AOC), Business, General and Military Aviation**	**Increased frequency and fidelity of accepted user preferences** **Reduced direct operating costs and improved schedule adherence**
Air Navigation Service Provider/FAA	**Reduced workload required to accept user preferences** **Reduced conflict-based corrective clearances through increased traffic predictability** **Greater airspace and airport capacity with reduced missed slots** **Greater motivation for airlines to equip with ADS-B and 4D FMS**
Traveler and Shipper	**Improved schedule adherence**

Sensis
CORPORATION

Detect the Difference

JPDO AATS Transformation Roadmap
Capability: 4D Trajectory Management

2006 2008   **2016**   **2025**

1. Datalink for 4DT communication

2. Ground processing of common flight object

3. Air-to-air transactional datalink

4. Arrivals TBM

7. Computer-assisted rerouting for TMIs

5. Departures TBM

6. En-route TBM

8. Strategic prediction w/4DT constraints

9. User-preferred strategic planning

10. Equity management & planning

IPT Linkages
• Shared Situational Awareness
• Weather
• Safety

11. 4DT automation HP testing & database

13. In-flight 4DT negotiation (strategic)

12. User-preferred preflight 4D filing (gate-2-gate)

14. Tactical 4DT separation planning/execution

15. 4DT strategic execution (closed loop)

16. Aircraft trajectory-based operations

17. Air-2-ground 4DT exchange

18. Air-2-air 4DT exchange

19. Air-2-air 4DT negotiation

20. 4DT safety monitoring & management

Independent safety monitors

21. Enhanced 4DT training & procedures

22. 4DT ROI data

Sensis
CORPORATION
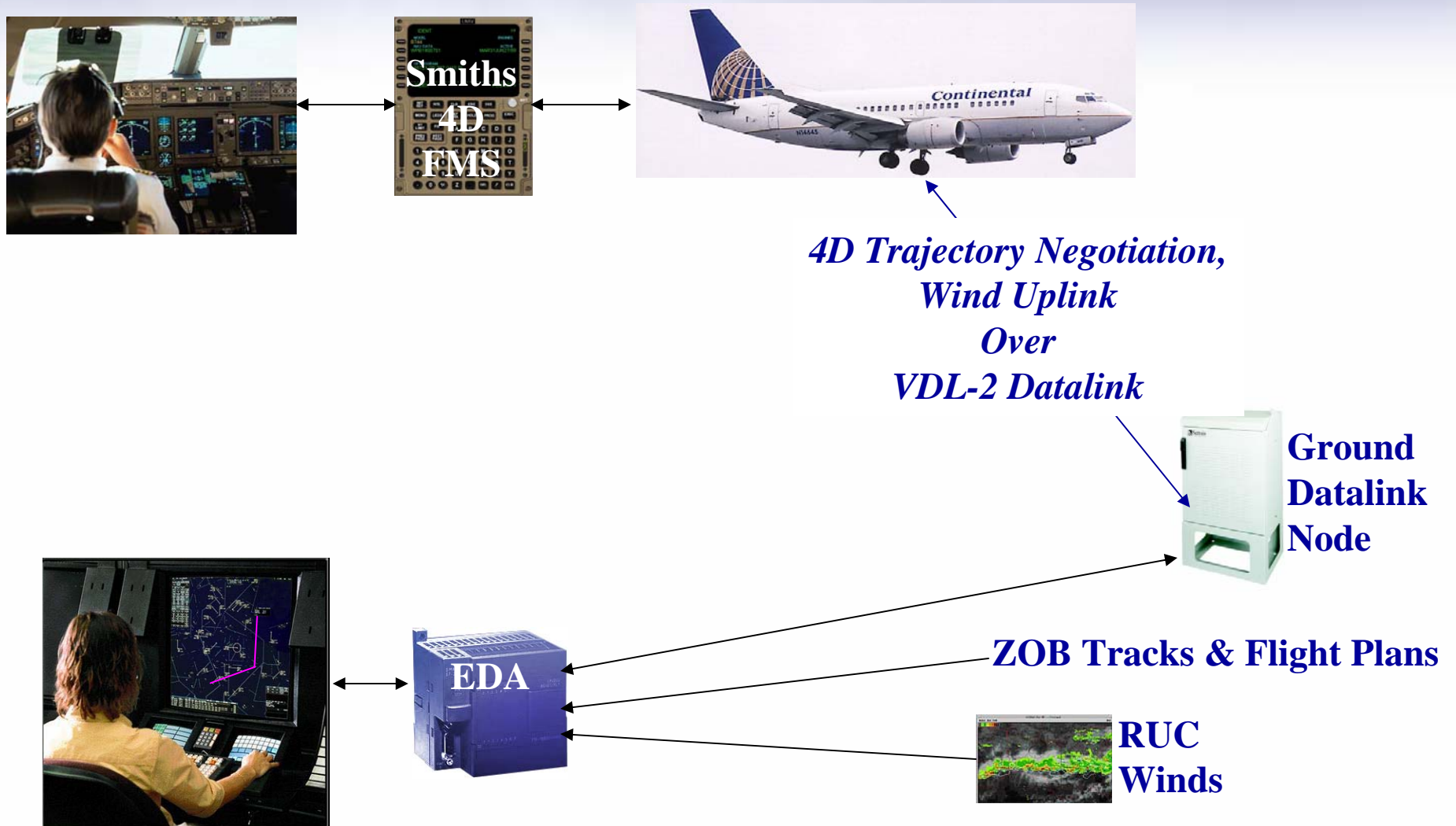
Last update: 6/14/05
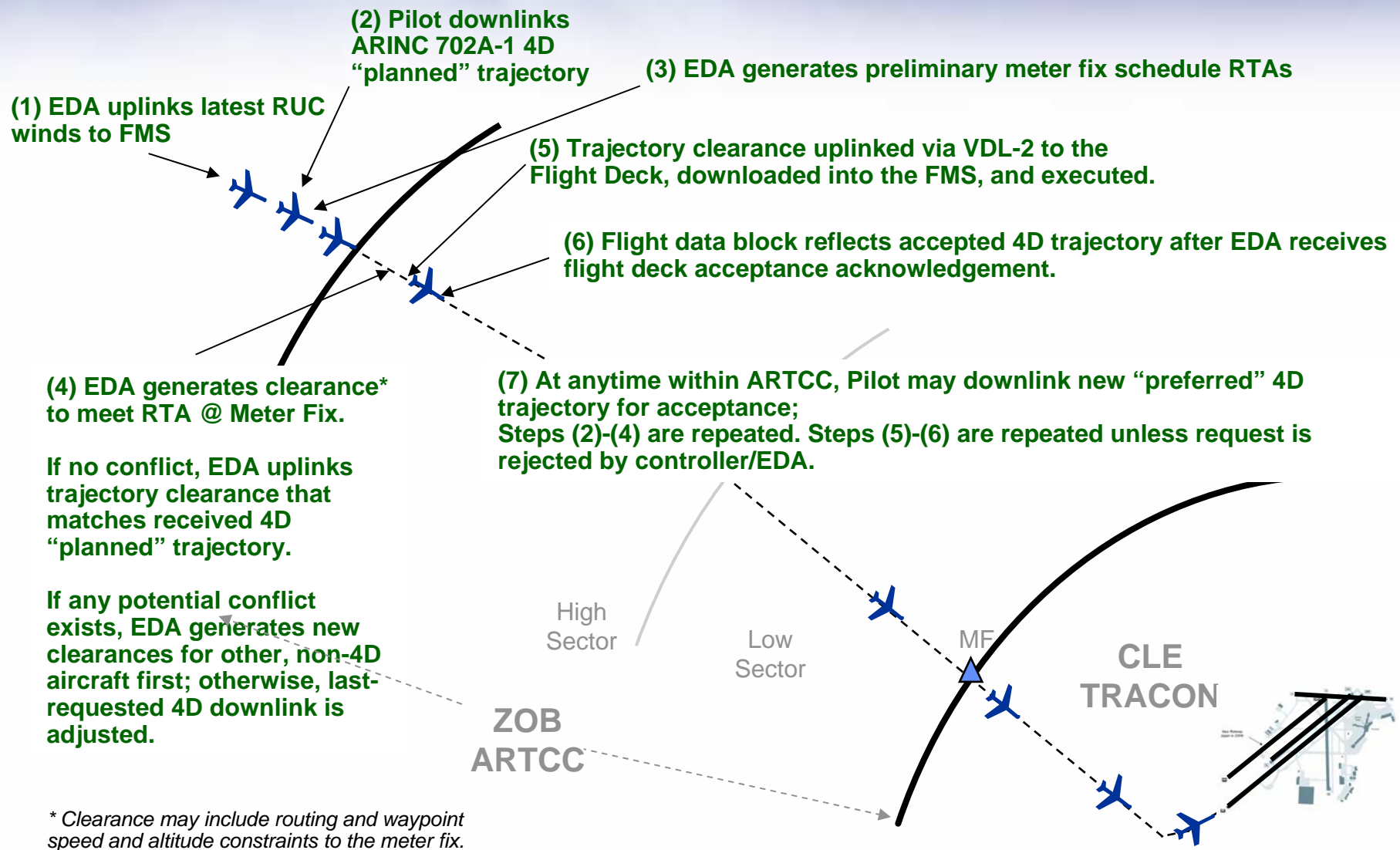
8

Detect the Difference

Scenario(s) / Experiment Planning:
Basic 4D En Route Experiment

- **Goal:** Establish technical and operational feasibility of 4DT negotiation

- **Method:**
  - Conduct series of experiments on 4D FMS-equipped arrivals into KCLE.
  - Adapt and Use 4D-capable NASA EDA for trajectory negotiation with revenue-carrying 4D FMS-equipped aircraft.

- **Timeframe:** Experiments conducted Fall 2007

- **Intended Audience:** JPDO and Air Transportation Stakeholders

- **Required Govt/Industry Partners:** FAA, NASA, Airlines, Avionics Manuf's

- **Resources Needed:**
  - **Aircraft and Aircraft Equipage:**
    - One Aircraft, optional: additional aircraft
    - 4D FMS, optional: 3D FMS
    - VDL-2 Datalink Radio with interface to FMS and flight crew
  - **Ground Infrastructure:**
    - Real-time ZOB Track and Flight Plan Data, RUC Wind Data Feed
    - NASA 4D-Enabled En Route Descent Advisor (4D-EDA)
    - VDL-2 Ground Datalink Radio with interface to 4D-EDA and ANSP

Sensis CORPORATION

Detect the Difference

4DT Experiment System Architecture

Smiths
4D
FMS

4D Trajectory Negotiation,
Wind Uplink
Over
VDL-2 Datalink

Ground
Datalink
Node

EDA

ZOB Tracks & Flight Plans

RUC
Winds

sensis
CORPORATION

Detect the Difference

Simplified ARTCC 4D Trajectory Roles and Procedures

(2) Pilot downlinks ARINC 702A-1 4D "planned" trajectory

(3) EDA generates preliminary meter fix schedule RTAs

(1) EDA uplinks latest RUC winds to FMS

(5) Trajectory clearance uplinked via VDL-2 to the Flight Deck, downloaded into the FMS, and executed.

(6) Flight data block reflects accepted 4D trajectory after EDA receives flight deck acceptance acknowledgement.

(4) EDA generates clearance* to meet RTA @ Meter Fix.

If no conflict, EDA uplinks trajectory clearance that matches received 4D "planned" trajectory.

If any potential conflict exists, EDA generates new clearances for other, non-4D aircraft first; otherwise, last-requested 4D downlink is adjusted.

(7) At anytime within ARTCC, Pilot may downlink new "preferred" 4D trajectory for acceptance; Steps (2)-(4) are repeated. Steps (5)-(6) are repeated unless request is rejected by controller/EDA.

High Sector

Low Sector

MF

CLE TRACON

ZOB ARTCC

* Clearance may include routing and waypoint speed and altitude constraints to the meter fix.

Sensis CORPORATION

11

Detect the Difference

Key Expected Experiment Results

- A *Feasibility Assessment* of integrating 4D airborne and ground automation systems with current day flight deck layouts

- Identification and Assessment of key 4D contract negotiation factors
  - E.g., roles and tasks, pilot response time, accuracy of predicted trajectory

- A Quantification of real-world differences in:
  - Airborne and ground state and intent information,
  - Future trajectory predictions by airborne and ground-based trajectory predictors,
  - Closed-loop RTA adherence performance

- Recommendations for future 4DT system development and performance standards for:
  - Future aircraft and ground decision support systems, surveillance, and datalink performance

Detect the Difference

Sensis 4D Trajectory Experiment Addresses Multiple Steps in JPDO AATS Transformation Roadmap

2006 2008   **2016**   **2025**

1. Datalink for 4DT communication

2. Ground processing of common flight object

3. Air-to-air transactional datalink

4. Arrivals TBM

7. Computer-assisted rerouting for TMIs

5. Departures TBM

6. En-route TBM

IPT Linkages
- Shared Situational Awareness
- Weather
- Safety

8. Strategic prediction w/4DT constraints

9. User-preferred strategic planning

10. Equity management & planning

11. 4DT automation HP testing & database

13. In-flight 4DT negotiation (strategic)

12. User-preferred preflight 4D filing (gate-2-gate)

14. Tactical 4DT separation planning/execution

15. 4DT strategic execution (closed loop)

16. Aircraft trajectory-based operations

17. Air-2-ground 4DT exchange

18. Air-2-air 4DT exchange

19. Air-2-air 4DT negotiation

Basic 4D En Route Experiment

20. 4DT safety monitoring & management

Independent safety monitors

21. Enhanced 4DT training & procedures

22. 4DT ROI data

13

Last update: 6/14/05

Detect the Difference

Core Elements of a Series of
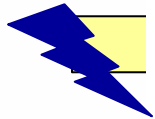# 4D Trajectory Experiments

Airborne Automation

| 4D Smiths FMS ARINC 702A-1 | 4D Smiths FMS ARINC 702A-3 + 3D FMS | 4D FMS + 3D FMS + Non-FMS |

Datalink

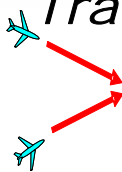| Existing ACARS/ VDL-2 | Time-Critical Datalink | Time-Critical Datalink |

Ground Automation

| 4D-EDA v1 | 4D-EDA v2 + 4D-Terminal Descent Advisor | 4D-EDA v3 + 4D-TDA v2 Incl. Wx |

Traffic Scenario

| Low Density | High Density | High Density with Weather |

Detect the Difference

Why This and Why Now?

Why This Set of Experiments?

- **According to JPDO, Use of 4D Trajectories is the "Coin of the Realm"**
  - **Expect significant airspace capacity improvements**
  - **Could be used to support "better-equipped, better-served" operations**

- **4D FMSs and VDL-2 Datalink Exist on Revenue-Carrying Aircraft Today**
  - **Effort to Modify EDA to Be 4D-Compatible Should Not Be Prohibitive**

- **Getting out in the Operational Realm early will help flush out key op'l constraints early to minimize time-to-initial operating capability**
  - **Early and frequent exposure of new concepts to operational domain has been a hallmark of previous NASA successes**

- **Starting 4D research focused on a Single 4D En Route Aircraft avoids safety-critical issues and can offer potential benefits immediately**

Why Now?

- **Need to start NOW to develop and test 4D operations if we have a hope of implementing this within the next decade**

Sensis CORPORATION

Detect the Difference

Next Steps

- **Investigating other concept options**
  - **Terminal Arrival 4DT**
  - **Departure 4DT**

- **Fleshing out details of 4D trajectory experiment architecture, and experiment plan**
  - **Working with Smiths and Rockwell-Collins to further understand 4DFMS and datalink limitations**

- **Looking for government and industry partnerships to make the 4DT concept a reality**

Detect the Difference